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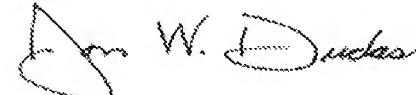
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This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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032204

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Additional inventors are being named on the _____ separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max)

DYNAMIC HALOGENATION OF SORBENTS FOR THE REMOVAL OF MERCURY FROM FLUE GASES

Direct all correspondence to: CORRESPONDENCE ADDRESS

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ENCLOSED APPLICATION PARTS (check all that apply)

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<input checked="" type="checkbox"/> Drawing(s) Number of Sheets	3	<input checked="" type="checkbox"/> Other (specify)	Return Postcard
<input type="checkbox"/> Application Data Sheet. See 37 CFR 1.76			

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<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.	FILING FEE Amount (\$)
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

 No. Yes, the name of the U.S. Government agency and the Government contract number are: _____

[Page 1 of 2]

Respectfully submitted,

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Date March, 22, 2004

REGISTRATION NO. 54,436

(if appropriate)

Docket Number. Case 7102

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Docket Number Case 7102

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Number 1 of 1

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DYNAMIC HALOGENATION OF SORBENTS FOR THE REMOVAL OF MERCURY FROM FLUE GAS

[001] BACKGROUND OF INVENTION

[002] Emissions Standards, as articulated by the U.S. Environmental Protection Agency (EPA), require assessment of hazardous air pollutants from utility power plants. Coal-fired utility boilers are a known source of anthropogenic mercury emissions in the United States. The EPA recently articulated the need to regulate mercury emissions from coal- and oil-fired utility units. Accordingly as elemental mercury and many of its compounds are volatile, conventional electric utility plant air pollution control methods fail to meet advancing EPA standard requiring new methods and processes to be developed.

[003] Mercury appears in coal combustion flue gases in both the solid and gas phases, particulate-bound mercury and vapor-phase mercury, respectively. Due to the high volatility of mercury and many of its compounds, most of the mercury found in flue gases is vapor-phase mercury. Vapor-phase mercury, can appear as elemental mercury (elemental, metallic mercury vapor) or as oxidized mercury (vapor-phase species of various compounds of mercury). Speciation, the form of mercury present, is a key factor in the development of mercury emissions control strategies.

[004] Particulate collectors in use at electric utility plants, most commonly electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses, provide high-efficiency removal of particulate-bound mercury. Fabric filters tend to exhibit better mercury removal than ESP's by providing more intimate contact between the flue gases and fly ash as the flue gases pass through the filter cake of fly ash on the filter bags. This intimate contact may promote the

Title: DYNAMIC HALOGENATION OF SORBENTS FOR THE REMOVAL OF MERCURY FROM FLUE GAS

adsorption of vapor-phase mercury species onto the fly ash or unburned carbon particles in the filter cake. Both wet and spray dryer absorber (SDA) flue gas desulfurization (FGD) systems remove significant amounts of oxidized mercury. Oxidized mercury, typically appearing in the form of mercuric chloride, is soluble in water, making it amenable to removal in sulfur dioxide scrubbers. Elemental mercury, insoluble in water, passes through most scrubbers. Removal of elemental mercury, therefore, remains an important issue in the search for cost-effective mercury control techniques.

[005] Numerous studies have been, and continue to be, conducted to develop cost-effective approaches to the control of elemental mercury. Many of the studies have focused on the injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas stream to adsorb vapor-phase mercury. The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components. PAC injection is used, commercially, to remove mercury from municipal waste combustor exhaust gases. PAC injection removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form. Although this approach appeared attractive in early work, the economics of high injection rates can be prohibitive when applied to coal-fired utility plants. More refined studies are now in progress to define more precisely what can and cannot be achieved with PAC. Still other studies seek to enhance PAC technology. One technique subjects the PAC to an impregnation process wherein elements such as iodine or sulfur are incorporated into the carbonaceous sorbent. Such processes can yield sorbents that more strongly bond with adsorbed mercury species, but also result in significantly higher sorbent cost.

[006] The speciation of vapor-phase mercury depends on coal type. Eastern U.S. bituminous coals tend to produce a higher percentage of oxidized mercury than do western subbituminous and lignite coals. Western coals have low chloride content compared to typical eastern bituminous coals. It has been recognized for several years that a loose empirical relationship holds between the chloride content of coal and the extent to which mercury appears in the oxidized form. Figure 1 illustrates the relationship between coal chlorine content and vapor-phase mercury speciation. An important reason for the significant uncertainty (scatter) in the data of Figure 1 is that mercury oxidation proceeds by both homogeneous and heterogeneous reaction mechanisms. Boiler convection pass and combustion air preheater temperature profiles, flue gas composition, fly ash characteristics and composition, and the presence of unburned carbon have all been shown to affect the conversion of elemental mercury to oxidized mercury species.

[007] It has been determined that the reactivity of conventional PAC (PAC that has not undergone special treatment such as iodine impregnation) with elemental mercury vapor is dependent upon the presence of acid gas species (e.g., hydrogen chloride and sulfur trioxide) in the flue gas stream. The presence of hydrogen chloride (HCl), in particular, has been shown to significantly improve the adsorption of elemental mercury from coal combustion flue gases. The hydrogen chloride is apparently adsorbed onto the carbon surface, facilitating the subsequent adsorption of elemental mercury. It is believed that an oxidized form of mercury is formed on the carbon surface. This phenomenon is of great practical importance for the application of PAC injection for mercury control for plants firing subbituminous and lignite coals. These coals tend to have very low chlorine content, and therefore produce combustion gases containing only small amounts of hydrogen chloride, and therefore would benefit significantly by the addition of hydrogen chloride in judicious ways.

[008] The dearth of halogen-containing gases can be further exacerbated if the PAC injection process is operating downstream of a sulfur dioxide scrubber, such as a wet or SDA FGD system. The scrubber removes acid gases such as hydrogen chloride in addition to the removal of sulfur dioxide. As an example, consider the application of PAC injection to a unit equipped with SDA FGD and a fabric filter that fires a low-chlorine coal. The concentration of hydrogen chloride in the flue gases resulting from the combustion of these coals is low. This concentration is further reduced by absorption in the SDA FGD system. This renders the PAC largely ineffective for elemental mercury capture in the SDA FGD and fabric filter. PAC must therefore be injected sufficiently far upstream of the SDA FGD to allow for the capture of mercury prior to the removal of the acid gases in the SDA FGD. This significantly limits the effective residence time available for mercury removal, and necessitates the use of high carbon injection rates. In addition to cost, high quantities of carbon can also limit ash disposal and/or utilization options.

[009] Felsvang, et. al. (U.S. Patent 5,435,980) teaches that the mercury removal of a coal-fired system employing an SDA FGD system can be enhanced by increasing the chlorine-containing species (e.g., hydrogen chloride) in the flue gases. Felsvang, et. al., further teaches that this can be accomplished through the addition of a chlorine-containing agent to the combustion zone of the of the boiler, or through the injection of hydrochloric acid (HCl) vapor into the flue gases upstream of the SDA FGD. These techniques are claimed to improve the mercury removal performance of PAC when used in conjunction with an SDA FGD system.

[0010] SUMMARY OF THE INVENTION

[0011] It is an object of this invention to provide an inexpensive effective method for increasing the concentration of hydrogen chloride, or other halogen-containing compounds, on the surface of the carbonaceous sorbent as the sorbent is conveyed to the injection location.

[0012] It is another object of this invention to introduce through experimental testing that the use of bromine-containing compounds are significantly more effective than chlorine-containing compounds in enhancing the capture of elemental mercury by carbonaceous sorbents.

[0013] It is a further object of this invention to introduce a method of mercury removal that is applicable to virtually all coal-fired utility power plants, including those equipped with wet or SDA FGD systems, as well as those plants equipped only with particulate collectors.

[0014] BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Fig 1 is Relationship between coal mercury content and mercury speciation for U.S. coals.

[0016] Fig 2 is a view of the Dynamic Halogenation of Sorbents for the Removal of Mercury from Flue Gases.

[0017] Fig 3 is a Mercury Removal with Dynamic Halogenation Using Hydrogen Bromide chart.

[0018] Fig 4 is a Coal-Fired Utility Plant Equipped with a Particulate Collector.

[0019] Fig 5 is a Coal-Fired Utility Plant Equipped with an SDA FGD and Particulate Collector.

[0020] Fig 6 is a Coal-Fired Utility Plant Equipped with a Wet FGD and Particulate Collector.

[0021] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

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[0022] The preferred embodiment of the current invention is illustrated in Figure 2. The system comprises conventional PAC injection system comprising a sorbent storage tank, a means for metering the sorbent into the sorbent transport air stream, a sorbent transport air blower supplying the air used to convey the sorbent to the injection locations in the flue gas duct(s), and a pick-up point where the sorbent is dispersed into the transport air stream. It should be recognized that this is only one embodiment of a pneumatic transport conveying system, and many other configurations could be used or developed by one of ordinary skill in the art without departing from the scope of the current invention. The key aspect of the current invention is that a halogen-containing gas is injected into the flowing transport air/sorbent stream at a point close to the point where the sorbent and transport air first mix. This is done to maximize the residence time available for the halogen-containing compound to be adsorbed onto the sorbent surface prior to the sorbent being injected into the flue gas duct. This process maximizes the benefit and utilization of the halogen-containing reagent by placing it exactly where it is needed to facilitate elemental mercury removal – on the surface of the sorbent. The sorbent particles with their loading of adsorbed halogen-containing reagent enter the flue gas duct with high reactivity for the removal of elemental mercury.

[0023] The present invention is advantageous to that of the prior art. The removal of elemental mercury from coal combustion gases generated by electric utility plants through the application of a conventional PAC injection process is very expensive. The current invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants. First, the process provides the benefits, in terms of reactivity with elemental mercury, of using an expensive, treated PAC sorbent (e.g., iodine-impregnated PAC) while using a conventional, low-cost sorbent.

[0024] Relative to the addition of chlorine-containing compounds to the flue gases as taught by Felsvang, et. al. (U.S. Patent 5,435,980), the invention makes much more efficient use of the halogen-containing reagent by placing onto the carbon sorbent surface prior to injection into the flue gases. It has been found by the inventors, and by several other investigators, that the addition of hydrogen chloride gas to the flue gases upstream of the PAC injection system, as taught by Felsvang, et. al., does not significantly improve the elemental mercury removal performance of the PAC injection process. This is due to the fact that much of the injected hydrogen chloride reacts with other flue gas constituents (e.g., calcium compounds contained in the coal fly ash particles), thereby preventing it from enhancing the performance of the injected PAC. By making efficient use of the halogen-containing reagent, the invention permits much lower addition rates for the halogen-containing reagent relative to other methods for halogen addition. The invention also has the significant advantage over other means of adding halogen-containing compounds to the flue gases in that boiler and other power plant components are not subjected to the corrosive nature of the halogen compounds. This is especially true when compared to the addition of halogens to the boiler combustion chamber. High-temperature corrosion of boiler components by chlorides is a well-known and serious concern.

[0025] The invention was tested in a 5 million Btu/hr Small Boiler Simulator (SBS) Facility. The SBS was fired at approximately 4.3 million Btu/hr with a western U.S. subbituminous coal. The During the tests flue gases exiting the SBS boiler first passed through a spray dryer absorber (SDA) for removal of sulfur dioxide, and then through a fabric filter for removal of fly ash and spent sorbent from the SDA FGD system.

[0026] A stream of dynamically-halogenated PAC, prepared by the method of the current invention, was injected into the flue gas stream downstream of the SDA FGD, and upstream of

the fabric filter. Hydrogen bromide was used as the halogen-containing reagent, and a commercially-produced PAC was used as the carbonaceous sorbent. Figure 3 illustrates the removal of mercury across the SDA/FF system during operation of the Dynamic Halogenation process. It can be seen that upon injection of the dynamically-halogenated PAC, the vapor-phase mercury exiting the system dropped from its initial value of approximately 6 ug/dscm to well below 1 ug/dscm. Other significant observations included: 1) PAC injection, alone, at a similar injection rate provided no discernable mercury removal (due to the absence of acid gases in the flue gases), 2) the use of hydrogen bromide was significantly more effective than the use of hydrogen chloride, and 3) the rates of addition of both the hydrogen bromide and PAC are many times lower than the rates for other halogen addition processes and conventional PAC injection processes, respectively. These results identify the current invention offers a cost-effective method of removing elemental mercury from coal combustion flue gases.

[0027] In an alternative embodiment, as illustrated in Figure 2, wherein the halogen-containing reagent is either hydrogen bromide or bromine (Br₂), a carbonaceous sorbent and halogen-containing reagent are brought together in the sorbent pneumatic transport line with sufficient residence time for the halogen-containing reagent to be adsorbed onto the carbonaceous sorbent particle before the sorbent is injected into the coal combustion flue gas stream.

[0028] In yet another embodiment the boiler fuel may be fired with, thus include, bituminous, subbituminous, and lignite coals and blends, thereof.

[0029] In yet another embodiment, the bromine-containing reagent could comprise hydrogen bromide gas (HBr) or bromine (Br₂).

[0030] In yet another embodiment, the halogen-containing gases may include any one or more of the following; hydrogen chloride, chlorine (Cl₂), as well as compounds of fluorine and iodine.

[0031] In yet another embodiment, the carbonaceous sorbents may include, but are not limited to, powdered activated carbon (PAC), carbons and chars produced from coal and other organic materials, and unburned carbon produced by the combustion process itself.

[0032] In yet another embodiment, the electric utility plant configurations may include plants equipped with an SDA FGD and particulate collector (Figure 4), a particulate collector (Figure 5), and a wet FGD and particulate collector (Figure 6).

[0033] In yet another embodiment, the spent carbonaceous sorbent can be removed separately from the coal fly ash, if desired, by adding an additional particulate collector designed specifically to capture the injected quantity of carbonaceous sorbent.

[0034] There are other alternative embodiment as would be obvious to one of skill in the art based on the teaching of the present invention, and are intended to be included within the scope of the claims of this invention.

I claim:

1. A method of reducing the mercury concentration of a flue gas comprising;
placing a halogen-containing reagent on a sorbent surface prior to injecting the sorbent surface into the flue gas.

2. A method of reducing the mercury concentration of a flue gas comprising the method as recited herein.

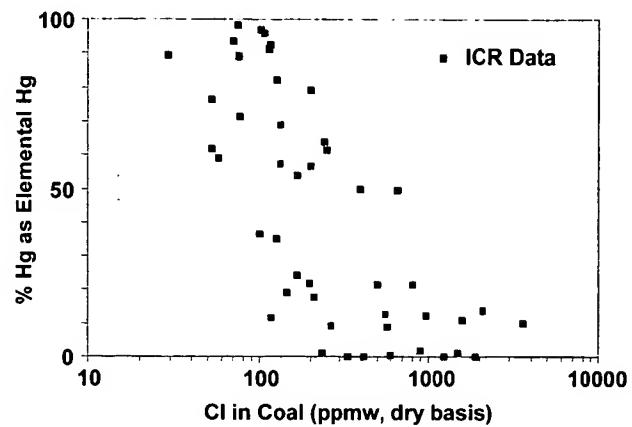


Fig. 1

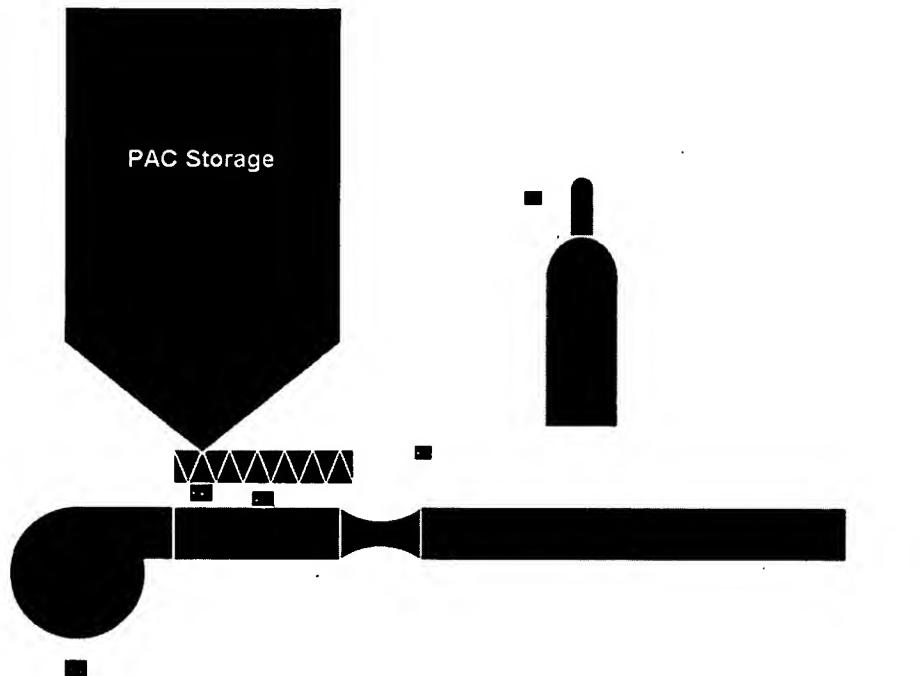


Fig 2

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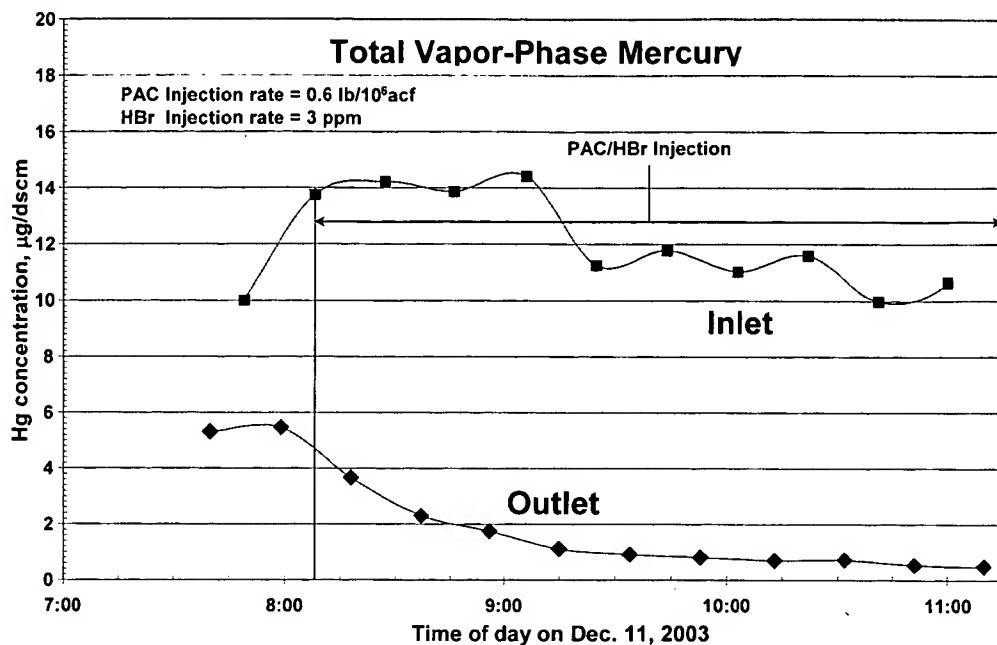
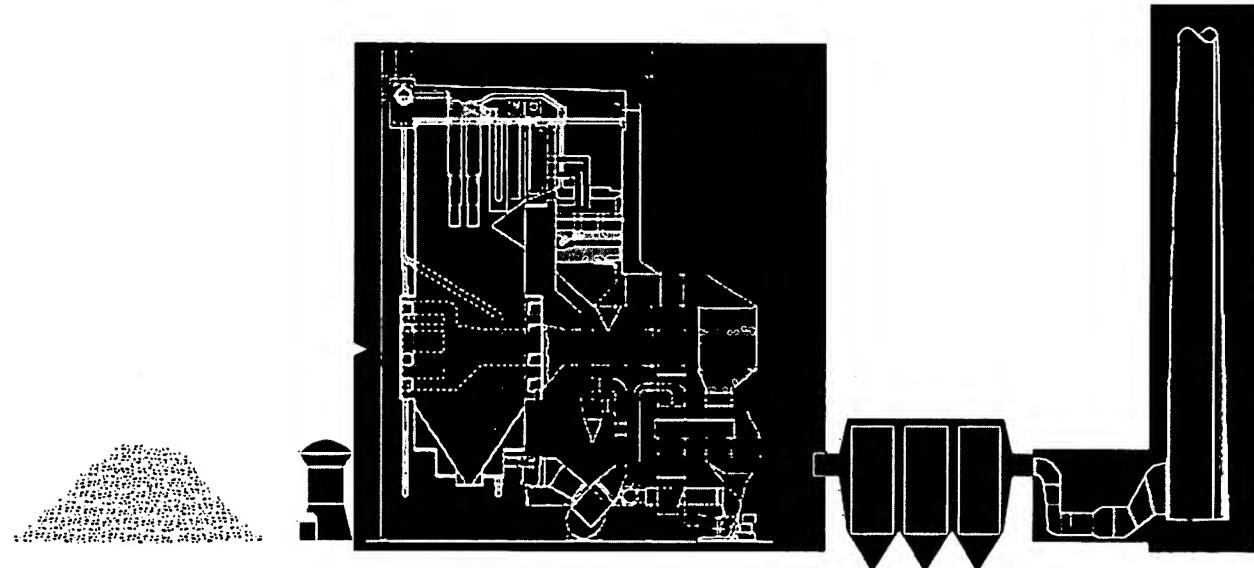


Fig 3



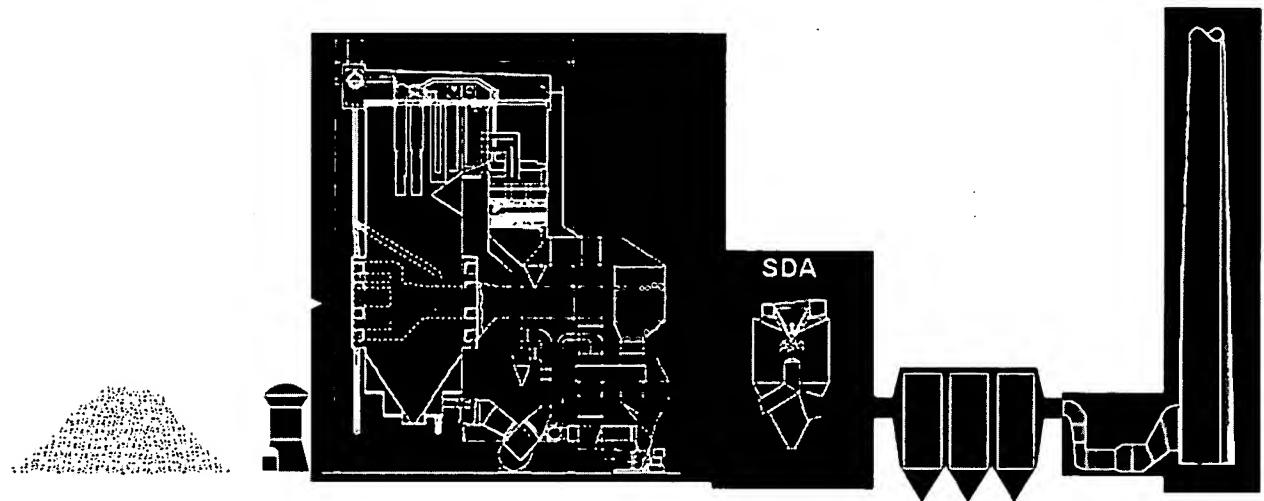


Fig. 5

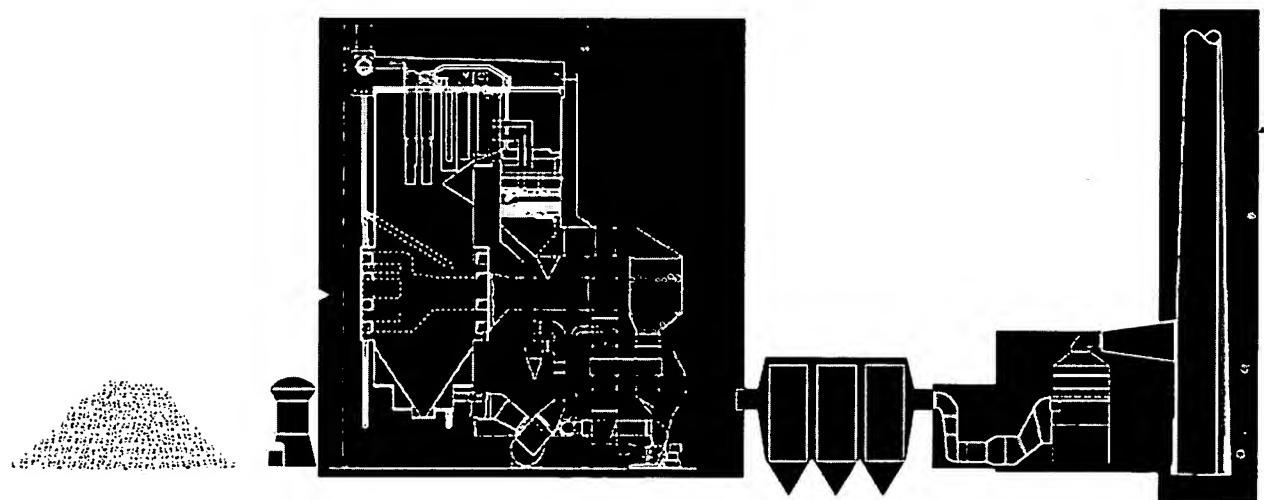


Fig 6

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